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User Guide to the Procedure for Determining Fenestration Product Condensation Index Rating

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National Fenestration Rating Council®

FOREWORD

The National Fenestration Rating Council, Incorporated (NFRC) has developed and operates a uniform rating system for energy and energy-related performance of fenestration products. The Rating System determines the U-factor, Solar Heat Gain Coefficient (SHGC) and Visible Transmittance (VT) of a product, which are mandatory ratings for labeling NFRC certified products, are mandatory ratings for inclusion on label certificates, and are supplemented by procedures for voluntary ratings of products for Air Leakage (AL), and Condensation Resistance. Together, these rating procedures, as set forth in documents published by NFRC, are known as the NFRC Rating System.

The NFRC Rating System employs computer simulation and physical testing by NFRC-accredited laboratories to establish energy and related performance ratings for fenestration product types. The NFRC Rating System is reinforced by a certification program under which NFRC-licensed responsible parties claiming NFRC product certification shall label and certify fenestration products to indicate those energy and related performance ratings, provided the ratings are authorized for certification by an NFRC-licensed certification and Inspection Agency (IA).

The requirements of the rating, certification, and labeling program (Certification Program) are set forth in the most recent versions of the following as amended, updated, or interpreted from time to time:

- NFRC 700 Product Certification Program (PCP).
- NFRC 705 Component Modeling Approach (CMA), Product Certification Program (CMA-PCP).

Through the Certification Program and the most recent versions of its companion programs as amended, updated, or interpreted from time to time:

- The laboratory accreditation program (Accreditation Program), as set forth in the NFRC 701 Laboratory Accreditation Program (LAP).
- The IA licensing program (IA Program), as set forth in NFRC 702 Certification Agency Program (CAP).
- The CMA Approved Calculation Entity (ACE) licensing program (ACE Program), as set forth in the NFRC 708 Calculation Entity Approval Program (CEAP).

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NFRC intends to ensure the integrity and uniformity of NFRC ratings, certification, and labeling by ensuring that responsible parties, testing and simulation laboratories, and IAs adhere to strict NFRC requirements.

In order to participate in the Certification Program, a Manufacturer/Responsible Party shall rate a product whose energy and energy-related performance characteristics are to be certified in accordance with mandatory NFRC rating procedures. At present, a Manufacturer/Responsible Party may elect to rate products for U-factor, SHGC, VT, AL, Condensation Resistance, or any other procedure adopted by NFRC, and to include those ratings on the NFRC temporary label affixed to its products, or on the NFRC Label Certificate. U-factor, SHGC and VT, AL, and Condensation Resistance rating reports shall be obtained from a laboratory that has been accredited by NFRC in accordance with the requirements of the NFRC 701.

The rating shall then be reviewed by an IA which has been licensed by NFRC in accordance with the requirements of the NFRC 702. NFRC-licensed IAs also review label format and content, conduct in-plant inspections for quality assurance in accordance with the requirements of the NFRC 702, and issue a product Certification Authorization Report (CAR), or approve for issuance an NFRC Label Certificate for site-built or CMA products and attachment products. The IA is also responsible for the investigation of potential violations (prohibited activities) as set forth in the NFRC 707 Compliance and Monitoring Program (CAMP).

Ratings for products that are labeled with the NFRC Temporary and Permanent Label, or products that are listed on an NFRC Label Certificate in accordance with NFRC requirements, are considered to be NFRC-certified. NFRC maintains a Certified Products Directory (CPD), listing product lines and individual products selected by the manufacturer/responsible party for which certification authorization has been granted.

NFRC manages the Rating System and regulates the Product Certification Program (PCP), Laboratory Accreditation Program (LAP) and Certification Agency Program (CAP) in accordance with the NFRC 700 (PCP), the NFRC 701 (LAP), the NFRC 702 (CAP), the NFRC 705 (CMA-PCP), and the NFRC 708 (CEAP) procedures, and conducts compliance activities under all these programs as well as the NFRC 707 (CAMP). NFRC continues to develop the Rating System and each of the programs.

NFRC owns all rights in and to each of the NFRC 700, NFRC 701, NFRC 702, NFRC 705, NFRC 707, NFRC 708 and each procedure, which is a component of the Rating System, as well as each of its registration marks, trade names, and other intellectual property.

The structure of the NFRC program and relationships among participants are shown in Figure 1, Figure 2, and Figure 3. For additional information on the roles of the IAs and laboratories and operation of the IA Program and Accreditation Program, see the NFRC 700 (PCP), NFRC 701 (LAP), and NFRC 702 (CAP) respectively.

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Figure 1

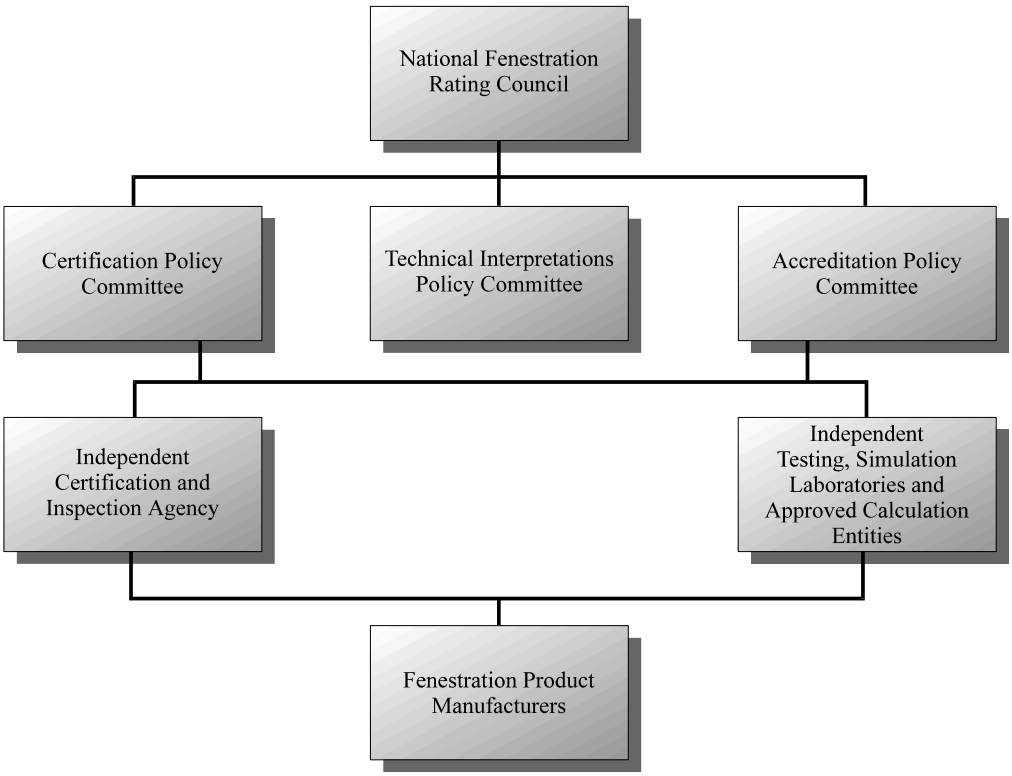
National Fenestration Rating Council
Certification Policy Committee
Technical Interpretations Policy Committee
Accreditation Policy Committee
Independent Certification and Inspection Agency
Independent Testing, Simulation Laboratories and Approved Calculation Entities
Fenestration Product Manufacturers

Figure 2

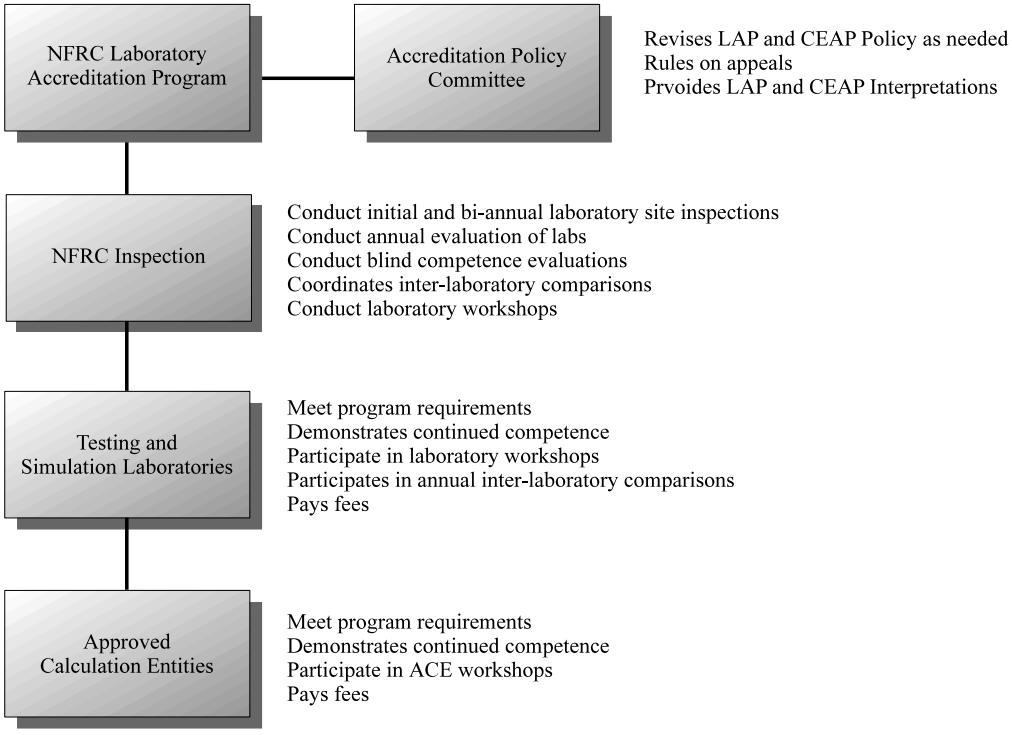

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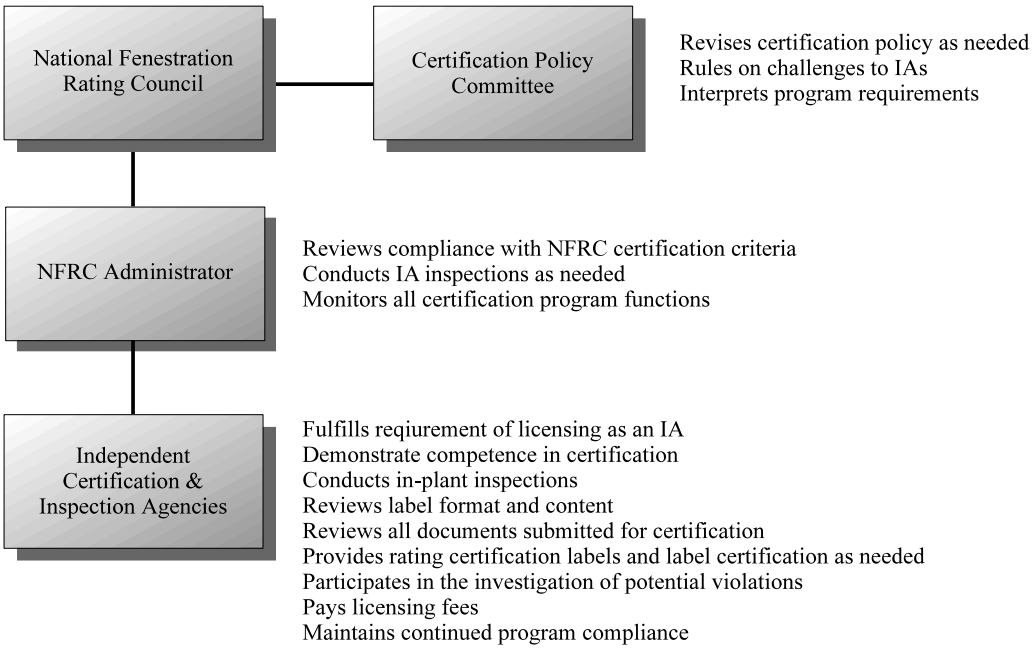
Figure 3


National Fenestration Rating Council
Certification Policy Committee
Revises certification policy as needed
Rules on challenges to IAs
Interprets program requirements
NFRC Administrator
Reviews compliance with NFRC certification criteria
Conducts IA inspections as needed
Monitors all certification program functions
Independent Certification & Inspection Agencies
Fulfills reqiurement of licensing as an IA
Demonstrate competence in certification
Conducts in-plant inspections
Reviews label format and content
Reviews all documents submitted for certification
Provides rating certification labels and label certification as needed
Participates in the investigation of potential violations
Pays licensing fees
Maintains continued program compliance

Questions on the use of this procedure should be addressed to:

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DISCLAIMER

NFRC certification is the authorized act of a Manufacturer/Responsible Party in: (a) labeling a fenestration or related attachment product with an NFRC Permanent Label and NFRC Temporary Label, or (b) generating a site built or CMA label certificate, either of which bears one or more energy performance ratings reported by NFRC-accredited simulation and testing laboratories and authorized for certification by an NFRC-licensed IA. Each of these participants acts independently to report, authorize certification, and certify the energy-related ratings of fenestration and related attachment products.

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1. UNDERSTANDING CONDENSATION PERFORMANCE

1.1 Purpose

ANSI/NFRC 500 provides a method of determining the Condensation Index for fenestration products to resist condensation via simulation or testing. The ANSI/NFRC 500 procedure provides a Condensation Index (CI) rating which can be determined for windows, doors, skylights, storefronts, site-built products and curtain wall systems. These products are included in the definition of fenestration products. For the purposes of the CI rating, a product is modeled and rated at a specified set of environmental conditions and at a specific size depending on the product type. The procedure rates the product at net zero air leakage, meaning that product air leakage is not considered.

The total product, comprised of all fenestration system components (such as frame, glazing and dividers), is evaluated for condensation potential with a Condensation Index (CI) rating established for the total product. Manufacturers are able to obtain Condensation Index (CI) ratings for all fenestration products specified in ANSI/NFRC 500. These include individual product designs using different combinations of glazing options, spacers and other components. NFRC-approved software tools are used to model and calculate a Condensation Index (CI) rating concurrently with U-factor, Solar Heat Gain Coefficient (SHGC) and Visible Transmittance (VT). In essence, four ratings can be obtained simultaneously by using the simulation software.

The use of NFRC-approved simulation tools also provides the user additional capabilities such as the ability to:

A. Evaluate the fenestration product condensation potential for different environmental parameters specific to job conditions (such as interior and/or exterior ambient temperatures and individual relative humidity).

B. Evaluate actual specified sizes.

C. Generate a colorized version of a thermo-graphic image that can provide better understanding of the product’s performance;

D. Obtain comparison of product performance by changing one or more components such as the glazing or a spacer in the model.

With the speed of today's computers, these tasks can be accomplished in a very short period of time.

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ANSI/NFRC 500 currently only addresses condensation, and the potential for formation of condensation, on the interior surfaces of a fenestration product. Condensation on the exterior of a product, or condensation that forms between glazing layers, is not considered and is not a part of the procedure.

1.2 Understanding Condensation and the Index Rating

The Condensation Index (CI) rating is the potential for the formation of objectionable condensation in either liquid or solid form at the specified environmental conditions per ANSI/NFRC 500 on the fenestration product.

Condensation forms when the surface temperature is at or below the dew point temperature of the surrounding air. To assist in preventing the formation of condensation, fenestration product manufacturers have to design their products with components having improved thermal performance. The purpose of this design effort is to raise the interior surface temperature above the dew point and, therefore, reduce the possibility of condensation forming on the interior of a product. Some of the components to be considered by a manufacturer while designing a fenestration product in order to get a condensation resistive product are as follows: frame systems fabricated from materials of low thermal conductivity and/or having thermal barriers (material of high resistance put in the path of heat transfer); warm-edge technology spacer systems that improve the resistance to heat flow; and high performance glazing.

Frame material properties, spacer systems and designs, and glazing types will, separately or in combination, affect the product's potential for the formation of condensation. The ability of manufacturers to design and modify fenestration products has been enhanced with the use of simulation software tools. Designers and simulators can readily change component materials and designs, and then calculate the resultant changes quickly and efficiently. Optimization of a particular design is enhanced by using the computer-assisted software tools.

A fenestration product typically has three distinct areas, or zones, that can be evaluated for the formation of condensation. Those areas are the frame/sash area, the edge-of-glazing area and the center-of-glazing area. The frame/sash is evaluated as one component, as is the center-of-glazing. The edge-of-glazing is the third area and is described in detail below. Divider and divider edge-of-glazing areas are considered part of the center-of-glazing area (see Figure 1-1).

The area that acts as an interface between the frame and center-of-glazing region is termed the edge-of-glazing. For the purpose of a

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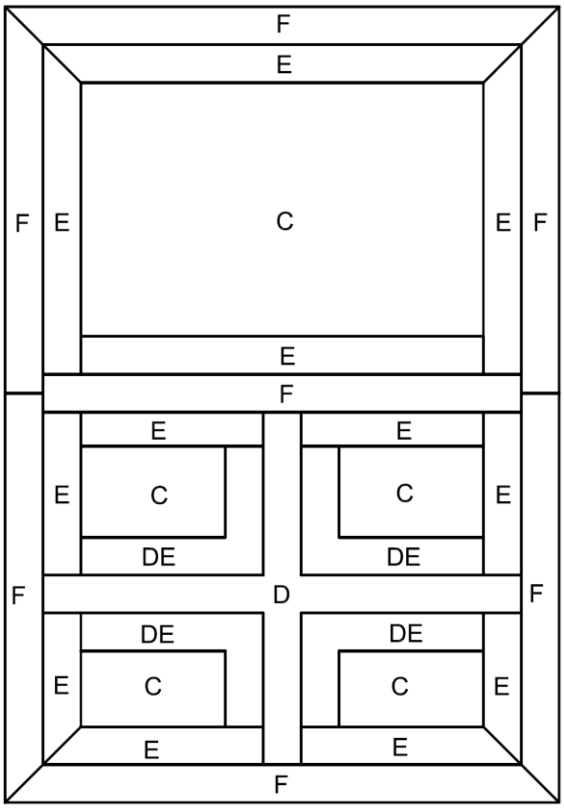
Condensation Index (CI) determination, the edge-of-glazing is represented by a single point measurement that is 25mm (1.0 in.) from the frame-to-glass junction towards the center-of-glazing, which may be at or below the sightline. This is not the same area utilized for the calculation of an edge-of-glazing U-factor.

Figure 1-1 -- Fenestration Product Schematic Vertical



LEGEND
C Center-of-Glazing
E Edge-of-Glazing
F Frame
D Divider
DE Edge-of-Divider

Because of the design and sometimes-complex nature of this edge-of-glazing area, as well as apparent differences in the rate of heat loss and interior surface temperatures, the edge-of-glazing area is considered separately.

Condensation will form first at the surface locations that exhibit the coldest surface temperatures. In most thermally efficient designs, condensation formation will occur at some location along the perimeter

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of the glazing before it will occur in the center-of-glazing region (condensation will form on the frame or sash first on a product that is metal without a thermal barrier and a thermally efficient insulating glass (IG) unit). If condensation is occurring in the center-of-glazing region before it appears at the perimeter, the air gap in the IG unit may be partially or totally collapsed at the center. An important component of this edge-of-glazing area is the spacer system. A spacer system, which is designed to be thermally efficient, will decrease the potential for condensation by allowing less heat transfer, and thus increasing the interior surface temperatures around the perimeter of the glazing. A spacer system that has a higher conductance may result in lower perimeter edge temperatures and thus may cause condensation to form.

Other design features which must be considered if applicable are dividers (internal grids or muntins) and true divided lites. The composition, location, and pattern, singularly or in combination, may have an effect on the formation of condensation. If the muntins are internal, the distance from the internal surfaces of the glazing may have an influence on the interior surface temperature of the glazing.

ANSI/NFRC 500 provides for the calculation of separate Condensation Index (CI) ratings for each of these three areas. The lower of the three values (CI_{frame}, $CI_{center\text{-}of\text{-}glass}$, and $CI_{edge\text{-}of\text{-}glass}$) is used as the Condensation Index (CI) rating of the total product.

In the realm of thermal performance of fenestration products, reducing or eliminating condensation is one of several fenestration product selection criteria that become increasingly important in cold climates. In addition to the aesthetic issue of reduced visibility or view, condensation can cause damage to curtains, carpets and wall finishes, cause mold and wood rot, lift paint and plaster, and eventually result in significant damage to other building materials and the fenestration product itself. Water contact with IG unit sealant may result in premature failure of the edge seals and thus result in reducing the overall product thermal performance.

The formation of condensation on the interior surfaces of fenestration products is dependent on a number of factors, which include environmental parameters such as the indoor air temperature, outdoor air temperature, and the relative humidity inside the building. As the outside temperature falls, areas of the fenestration product's interior surfaces may fall below the dew point temperature. The dew point temperature is a function of the relative humidity of the air. The higher the relative humidity will result in a higher dew point temperature. This means that with the same fenestration product surface temperature conditions, condensation will occur sooner in a space with a higher

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indoor relative humidity. Measured winter relative humidity levels in buildings typically vary between 20 and 70 percent.

The NFRC Condensation Index (CI) scale is 1-100, with a higher CI number representing less potential for the formation of condensation. The Condensation Index (CI) rating is determined based on outside conditions of approximately -18ºC (-0.4ºF) with a 5.5m/s (12.3mph) wind, and inside conditions of approximately 21ºC (69.8ºF) The Condensation Index (CI) is based on the coldest temperature of the frame/sash, center-of-glazing, or edge-of-glazing Condensation Index (CI). The lower of the frame/sash, center-of-glazing, or edge-of-glazing Condensation Index (CI) values shall be the total product rating.

The Condensation Index (CI) rating is determined for very specific environmental conditions. When installed in a building, there are numerous uncontrolled, site specific factors that may affect the formation of condensation on the fenestration product, including installation details, site geometry, wind speed and direction, and fenestration product coverings, to name a few. In this procedure, the Condensation Index (CI) rating is meant to apply only to the exposed interior fenestration product surfaces under cold winter conditions. The procedure does not address the issue of condensation on the exterior fenestration product surface as can occur during seasons other than winter.

To decrease the potential for the formation of condensation, it is important to maintain the surface temperature of the fenestration products above the dew point. To accomplish this, fenestration product manufacturers must reduce the amount of heat that passes through a fenestration product in the form of *thermal transmittance* (U-factor). Heat from inside the building will conduct its way through the parts of the fenestration product that are the least energy efficient (i.e., are highly conductive), causing those parts to have lower indoor surface temperatures. This increases the potential for condensation on and around these less energy efficient parts of the fenestration product.

Other ways to decrease the potential for condensation on fenestration products are controlling the indoor temperature, relative humidity and air circulation. Individually, or in combination, these factors can reduce the possible formation of condensation. Increasing the indoor air temperature would increase the dew point; however, there are potentially adverse affects in increased heating bills. Reducing the relative humidity in a living space to slightly above or at 30 percent, the lower limit of human comfort, would lower the dew point. The movement of air over the surface of a fenestration product increases the evaporation rate of moisture, and thus slows the formation of moisture on the surface. Many homes and offices have some type of

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interior window treatment, such as blinds or drapes. While blinds and drapes are typically beneficial in the reduction of heat loss, they can adversely increase the potential for condensation. In the closed or partially closed position, the interior surface temperatures of the fenestration product could be decreased, and if they are decreased below the dew point temperature, condensation formation takes place.

2. PHYSICAL FACTORS AFFECTING CONDENSATION

2.1 Environmental Factors

NFRC uses specific conditions for the purpose of rating and comparing products. However, real world environmental conditions are not constant, and are a function of the surroundings to which the product is exposed. There are a number of environmental variables, singularly or in combination, which can have a significant influence on the performance of a fenestration product for the formation of potential condensation.

Environmental factors that can influence the potential for condensation formation are exterior wind, interior air movement, relative humidity, localized interior and exterior ambient temperatures at the product surfaces, and the temperatures the product is radiating to (e.g., during night time conditions and a clear sky, the radiant temperature will be lower than the localized air temperature at the exterior of the product). Specific rooms within a building can be influenced by the activities occurring in those rooms. Bathrooms and the kitchen are two rooms that may experience high humidity levels as a result of bathing or cooking. Rooms with large numbers of plants such as conservatories or sunrooms may also experience both higher humidities and higher than normal temperatures. High occupancy buildings, such as dormitories, may experience high humidity due to the concentration of people in those buildings. Special treatment rooms such as natatoriums or burn recovery rooms may be designed for high relative humidities. When selecting a Condensation Index (CI) rating it is important to review and understand the environmental factors to which the fenestration product(s) will be exposed. A detailed analysis that addresses the required environmental factors may be required.

2.2 Effect of Change in Temperature:

The properties of air and water vapor mixtures are relatively well known. Changes in these properties with heating and cooling can be followed readily with the aid of a psychrometric chart, represented in

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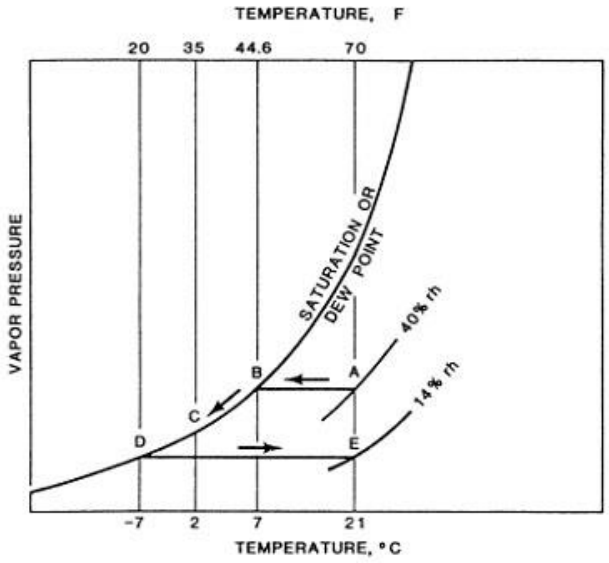
Figure 2-1. The saturation line represents the limiting concentrations of water vapor, which can exist as vapor at various temperatures.

The indoor condition of 21ºC (69.8ºF) and 40 percent relative humidity (RH) is represented by point A. This is a condition of partial saturation; i.e., less than 100 percent RH. The actual vapor pressure of the water present in the air, although not shown in the chart, can be calculated readily from the vapor pressure at saturation and the RH, since RH is approximately the ratio of the actual vapor pressure to the saturation pressure at the existing temperature, expressed as a percentage.

The increased RH accompanying cooling from condition A on the chart to point B can be readily followed. At B, 7ºC (45ºF), the RH becomes 100 percent and the air/vapor mixture is said to be saturated. On further cooling to 2ºC (35ºF), the original amount of water vapor can no longer be retained and is reduced by condensation to condition C. The process illustrated by ABC is typically that which an air/vapor mixture experiences when in contact with a cool fenestration product surface. Cooling from B to C results in visible condensation on the fenestration product components. If point C were below 0ºC (32ºF), the condensate would be frost, and in more severe conditions, ice.

Figure 2-1 -- Psychometric Chart of Dew Point Curve



Once the temperature drops below the dew point, or frost point if below 0ºC (32ºF), the vapor pressure at the condensing surface is also reduced, establishing a gradient of vapor pressure from room air to the fenestration product surface. This gradient with convective action within the room will move water vapor continuously to the fenestration product surface, causing it to be condensed, so long as the concentration of water vapor in the room is maintained.

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2.3 Fenestration Product Design Factors

Fenestration product manufacturers and the designers responsible for improving the energy efficiency of fenestration products have many new or improved technologies that are now available to them that many years ago were either not developed or were still in developmental stages. The use of lower conductivity frame materials reduces the possibility of the formation of condensation. Improvements in glazing technology with the advent of low emissivity coatings, inert gas-fills used in the air space cavities, tints/coatings/films, and low conductivity spacer systems (warm edge technology) have all added to the selection of components and materials that the manufacturer has at their disposal to improve the energy performance, and reduction in the potential for condensation formation, of their products.

3. DEFINITIONS

Reference NFRC 600: Glossary and Terminology

4. DETERMINATION OF CONDENSATION RESISTANCE INDEX (CI) RATING

The first and primary method is using NFRC-approved simulation tools for the determination of the Condensation Index (CI) rating. The fenestration product shall be simulated in accordance with an NFRC-approved software tool that includes a multi-element gray-body diffuse radiation model and detailed convection modeling inside all glazing cavities.

A second method, that of physical testing, shall be used only in the case where a fenestration product cannot be accurately simulated using currently approved NFRC software tools. In this instance, physical testing is the only alternative offered to obtain Condensation Index (CI) ratings. The test can be performed simultaneously during the U-factor test using NFRC 102. For Condensation Index (CI) evaluation, additional thermocouples are attached to the interior surface of the test specimen in pre-specified locations.

4.1 Simulation Requirements for Condensation Resistance Rating

Since both temperature and surface film coefficients affect the results, standardized conditions are used for calculation of the Condensation Index (CI) rating.

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A. Interior ambient temperature of 21.0ºC (69.8ºF).

B. Exterior ambient temperature of -18ºC (-0.4ºF).

C. Exterior wind speed of 5.5 m/s (12.3 mph).

D. Sky condition of 100 percent cloud cover.

Current NFRC procedures provide allowances for the use of computer simulation tools capable of 2-D conduction and radiation heat transfer analysis, and convection heat transfer analysis in glazing cavities.

4.2 Calculation of the Condensation Rating

The calculation of a Condensation Index (CI) rating for a fenestration product is performed by analyzing each section of the fenestration product; i.e. frame and sash, edge-of-glazing, dividers, edge-of-divider, door panel, door panel edge, and center-of-glazing. These section's THERM models are evaluated to determine the coldest temperature point (except for center-of-glazing is taken directly from the Berkeley Lab WINDOW glazing library) then the coldest temperature is used to compute the Condensation Index (CI). See Equations 4-1 through 4-3 for illustration of this concept.

$CI_f = ((T_{frame} - T_c) / (T_h – T_c)) \times 100;$ Equation 4-1

$CI_c = = ((T_{cog} - T_c) / (T_h – T_c)) \times 100;$ Equation 4-2

$CI_e = = ((T_e - T_c) / (T_h – T_c)) \times 100;$ Equation 4-3

Where:

CI_f = Condensation Index of Frame

CI_c = Condensation Index of Center-of-Glazing (including divider and divider-edge)

CI_e = Condensation Index of Edge-of-Glazing or Door Lite Edge

T_{frame} = Coldest Temperature from the surfaces of Frame, Sash, Panel or Panel Edge

T_{cog} = Center-of-Glass Temperature

T_e = Coldest Temperature of all the glazing edges

T_c = Ambient Exterior Cold Air Temperature of -18 C

T_h = Ambient Interior Warm Air Temperature of 21 C

Details on how to evaluate each cross section and determine their corresponding coldest surface temperatures for use in calculating Condensation Index (CI) for the frame, center-of-glazing, and edge-of-glazing for the whole fenestration product are stipulated in ANSI/NFRC

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500. The final Condensation Index (CI) rating is the minimum value of the Condensation Index Rating of the frame, Condensation Index Rating for the center-of-glazing, and the Condensation Index (CI) Rating for edge-of-glazing values.

As the Condensation Index (CI rating number increases, the fenestration product's ability to resist the formation of condensation increases.

5. CALCULATION OF CONDENSATION INDEX (CI) RATING USING THE PHYSICAL TEST PROCEDURE

In the case of physical testing, temperature sensors known as thermocouples are attached to the interior of the specimen. The temperatures are configured in a pre-specified arrangement to adequately area-weight specific area segments of the specimen with a measured temperature. Calculations are then performed to determine area-weighted temperatures for each defined area of the specimen. Additional calculations are then performed in accordance with the ANSI/NFRC 500 procedure to determine the Condensation Index (CI) rating for each of the three designated regions: the frame, the center-of-glazing, and the edge-of-glazing.

Standardized test conditions are used for the evaluation and rating of the Condensation Index (CI), which are defined in the NFRC 102 document.

The determination of a Condensation Index (CI) rating for a particular fenestration product is performed using the same calculation methods, whether the simulation or test only method is used. However, when the computer modeling is performed with NFRC-approved software, the temperature location is not area-weighted so the simulator shall find the coldest temperature manually. For the physical test procedure, determining the exact location of the coldest temperature along the frame/sash and/or glazing edge is not a feasible task for testing laboratories. Therefore, the area segment considered during testing is larger than the segment considered for simulation. The area segment considered may have temperature variations, and therefore an area-weighted temperature calculation is performed by measuring the temperature using a thermocouple placed at the center of a representative area and then calculating the average representative temperature for the segment. These measured area-weighted temperatures are then used in the equations specified in ANSI/NFRC 500 to calculate separate Condensation Index (CI) ratings of the frame, the center-of-glazing, and the edge-of-glazing.

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When determining a Condensation Index (CI) rating, the user of the ANSI/NFRC 500 procedure determines the coldest temperature from the array of thermocouples mounted to the pre-determined frame and divider location. The next step is to calculate the Condensation Index (CI) of the frame/sash, edge-of-glazing, and center-of-glazing (including divider when applicable) Section 5.3 of ANSI/NFRC 500. Finally, a determination is made of the total product Condensation Index (CI) rating of the frame/sash, the center-of-glazing, and the edge-of-glazing is the lower CI of the three sections as defined in ANSI/NFRC 500.

6. RATINGS AND SIZES

NFRC provides a fair, accurate, and credible rating system for thermal performance properties such as U-factor, Solar Heat Gain Coefficient (SHGC), Visible Transmittance (VT) and Condensation Index (CI). Size is an important characteristic of the product when considering comparison of these ratings from product to product. Variation in the size of the product can be important when any of these ratings are considered because size affects the area ratios of the frame, edge-of-glazing and center-of-glazing. The Condensation Index (CI) is a total product rating and is evaluated using three distinct areas: the center glazing area (comprised of the center-of-glazing, divider, and edge-of-divider), the edge glazing area (comprised of the edge-of-glazing and the door lite edge), and the frame area (frame, sash, door panel, and door panel edge components) for specific sizes of a fenestration product. Differing sizes of the same product may have different ratings.

NFRC has addressed the size issue for each operator type and provides referenced sizes for comparison purposes. The current sizes can be found in Table 4-3 of ANSI/NFRC 100. Table 4-3 provides standardized sizes for the following general categories: windows, doors, glazed wall systems/sloped glazing, and sidelites/transoms.

ANSI/NFRC 500 provides ratings at specific environmental conditions for comparative purposes only. The procedure is not intended to predict or evaluate the formation of condensation; the amount of, or locations of, the condensation; the severity of the condensation; or the performance characteristics at varying environmental conditions.

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7. EXAMPLES USING THE CONDENSATION INDEX (CI) RATING

The calculated Condensation Index (CI) value can be a useful design tool for the purchasing consumer/buyer of a fenestration product. Much like the consumer may search for the most advantageous U-factor, Solar Heat Gain Coefficient (SHGC), and/or Visible Transmittance (VT) for their home or building in a certain region of the US and Canada, the Condensation Index (CI) can also be researched for the for most potential.

Below are examples of how the Condensation Index (CI) rating can be used knowing that it was derived based on ANSI/NFRC 500 environmental conditions. This is important to understand because the indoor air temperature of the home/building shall always be assumed to be 21°C (70°F). The Winter Design Temperature/CI Table (7-1) below requires some interpolation when your dew points, relative humidities, or winter design temperatures fall in-between the posted values.

The header titled Winter Design Temperatures posted in Table 7-1 were derived from Equation 2 of the paper published by Hakim Elmady titled, *A Universal approach to laboratory assessment of the condensation potential of windows*. These are calculated temperatures to be used in combination with the ASHRAE Handbook of Fundamental Winter Design Temperatures posted for many weather station cities within the USA and Canada. For these examples, only the 99% Winter Design Temperatures were used and may be obtained from ASHRAE Fundamentals Handbook – Chapter 27, Climatic Design Information. See the "Heating Dry Bulb" columns of Tables 1A and 2A for the United States and Canada, respectively.

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Table 7-1 Winter Design Temperature / Condensation Index (CI) Table

		Winter Design Temperature, Td (Celsius)								
	*Dew Point Temp,	0	-5	-10	-15	-20	-25	-30	-35	-40
RH%	Ts, °C	Condensation Index, CI								
10	-12	----	----	----	8	20	28	35	41	46
15	-7	----	----	10	22	32	39	45	50	54
20	-3	----	8	23	33	41	48	53	57	61
25	0	0	19	32	42	49	54	59	63	66
30	3	14	31	42	50	56	61	65	68	70
35	5	24	38	48	56	61	65	69	71	74
40	7	33	46	55	61	66	70	73	75	77
45	9	43	54	61	67	71	74	76	79	80
50	10	48	58	65	69	73	76	78	80	82
55	12	57	65	71	75	78	80	82	84	85
60	13	62	69	74	78	80	83	84	86	87
65	14	67	73	77	81	83	85	86	88	89
70	15	71	77	81	83	85	87	88	89	90
75	16	76	81	84	86	88	89	90	91	92
80	17	81	85	87	89	90	91	92	93	93

*Note: Dew Point is calculated based on 21°C (69.8°F) indoor air temperature

Example 1: Find Potential Condensation Index (CI) of Rated Fenestration Product

The Building Owner is to build a multi-family condominium complex in Mason City, Iowa and does not want the interior dew point of the windows to drop below 9°C at an interior relative humidity (RH) of 45%. The Winter Design Temperature of Mason City, IA = -23°C as found in the ASHRAE Handbook chart. What CI rating of the windows shall the owner be looking to target?

The Condensation Index (CI) of the windows shall be about 72.

		Winter Design Temperature, Td (Celsius)								
	*Dew Point	0	-5	-10	-15	-20	-25	-30	-35	-40
RH%	Temp, Ts, °C	Condensation Index, CI								
45	9	43	54	61	67	71	74	76	79	80

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Example 2: Find a Reasonable Relative Humidity to Not Exceed

A homeowner purchased windows with a Condensation Index (CI) Rating of 63 but after making the purchase was concerned about minimizing condensation potential since the relative humidity in the home is mostly around 50% throughout the winter in Chattanooga, Tennessee. The Winter Design Temperature of Chattanooga = -7°C as found in the ASHRAE Handbook chart.

Based on Table 7-1, at -7°C Winter Design Temperature and RH% of 50, the CI of the window is recommended to be 61 or higher. The purchased windows had a CI of 63 and since that meets or exceeds the recommended 61, this homeowner is satisfied.

		Winter Design Temperature, Td (Celsius)								
	***Dew Point Temp, Ts, °C**	0	-5	-10	-15	-20	-25	-30	-35	-40
RH%		**Condensation Index, CI**								
50	10	48	58	65	69	73	76	78	80	82

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Example 3: Interpolating and Using Same Type Windows for Two Home Regions

A resident has a home in Omaha, Nebraska, the Winter Design Temperature for that location is -19°C. The resident has windows in that home that he really likes for it performs satisfactorily for condensation potential and the home stays at 40% RH or less. This resident likes these windows so much that the plan is to purchase same windows for a 2nd home in Winslow, Arizona. The concern is will these same windows perform just as well in the 2nd home for the potential for condensation?

The homeowner does not know the CI rating of the Omaha windows but the chart in Table 7-1, when interpolated for -19°C along the 40% RH row and under the Winter Design Temperatures of -15°C and -20°C, is about a CI of 65. The Winter Design Temperature (WDT) for Winslow, Arizona is -10°C and does plan to humidify the indoor room air to be maintained at 50% RH. Table 7-1 indicates that at -10°C WDT and 50% RH, the CI is 65. Conclusion is yes, the same window systems purchased for Omaha, Nebraska is satisfactory for the 2nd home in Winslow, Arizona.

		Winter Design Temperature, Td (Celsius)								
	***Dew Point**	0	-5	-10	-15	-20	-25	-30	-35	-40
RH%	**Temp, Ts, °C**	**Condensation Index, CI**								
40	7	33	46	55	61	66	70	73	75	77
45	9	43	54	61	67	71	74	76	79	80
50	10	48	58	65	69	73	76	78	80	82

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Example 4: Dew Point

A new management company took over a condo complex in Fort St. John, British Columbia is updating pressure equalization equipment in the building and is concerned with the introduction of humid air from the corridor into each unit. The intent is to keep the corridors at an RH of 35-40% and the windows specified to be installed have a Condensation Index (CI) Rating of 65. The owner expects the surface temperatures of the glazing edges to be around 4°C. The 99.0% Winter Design Temperature of Fort St. John = -30°C. What is the expected dew point of this window system?

Per Table 7-1, the dew point at 35% and 40% RH with the standardizes indoor air temperature at 21°C is 5°C to 7°C, respectively. The owner's expected surface temperatures at the glazing edge of 4°C is below the tabled dew point range. It is therefore recommended that the owner lower the building's corridor RH range from 25-30% or seek window systems with a minimum Condensation Index (CI) rating of 69 is specified.

		Winter Design Temperature, Td (Celsius)								
	***Dew Point Temp, Ts, °C**	0	-5	-10	-15	-20	-25	-30	-35	-40
RH%		**Condensation Index, CI**								
30	3	14	31	42	50	56	61	65	68	70
35	5	24	38	48	56	61	65	69	71	74
40	7	33	46	55	61	66	70	73	75	77

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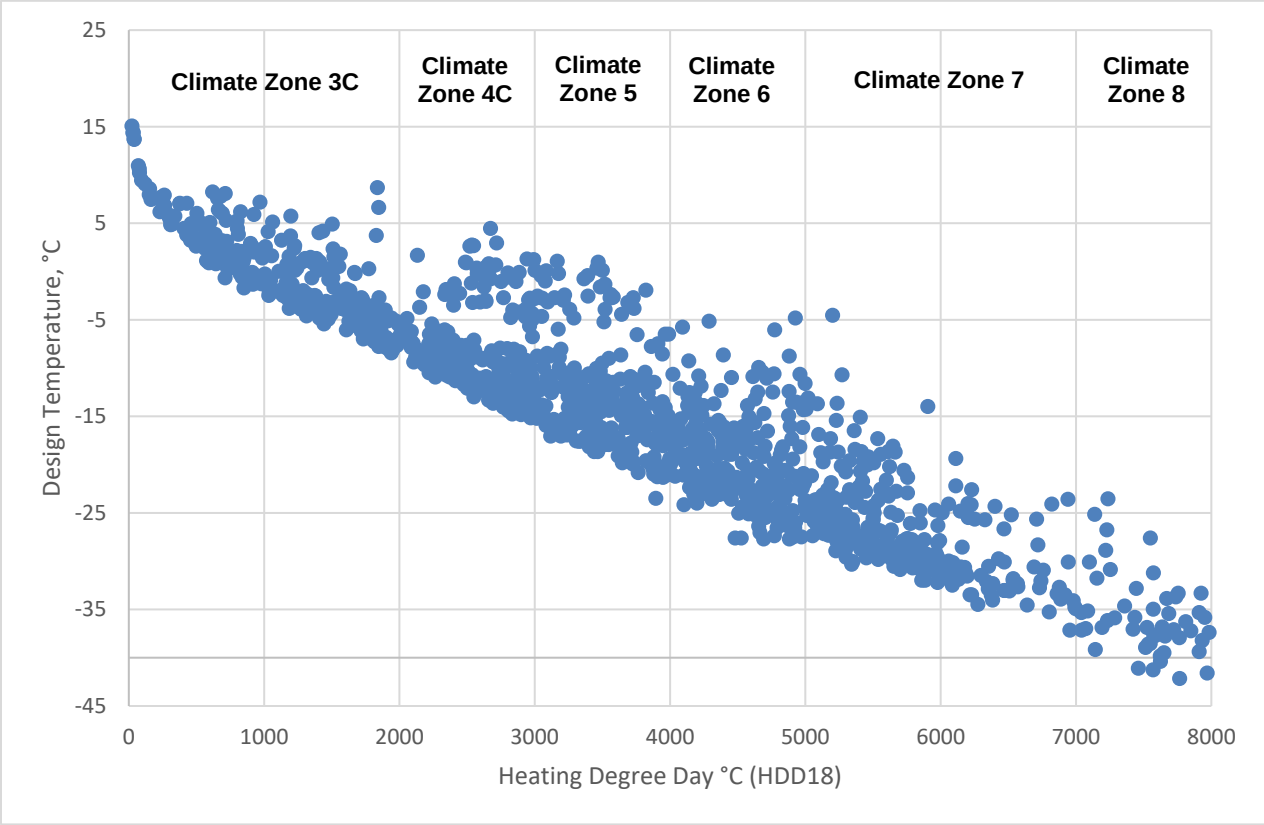
Figure 7-1 Winter Design Temperature versus Climate Zones 3-8



The above Figure 7-1 is a plot of the winter design temperatures of many cities from the USA and Canada.

Table 7-2 International Climate Zone Number Definitions for HDD

(source: Table C301.3(2) of 2018 *International Energy Conservation Code*)

Climate Zone	Heating Degree Days Climate Zone Ranges	
	SI Units (Base Temperatures of 18°C)	IP Units (Base Temperatures of 65°F)
3C	HDD ≤ 2000	HDD ≤ 3600
4C	2000 < HDD ≤ 3000	3600 < HDD ≤ 5400
5	3000 < HDD ≤ 4000	5400 < HDD ≤ 7200
6	4000 < HDD ≤ 5000	7200 < HDD ≤ 9000
7	5000 < HDD ≤ 7000	9000 < HDD ≤ 12600
8	7000 < HDD	126000 < HDD

The climate zones are a picture of how warm or cold it for various parts of the world but specifically to North America, climate zone 1 as the hottest (southern-most tip of Florida) to climate zone 8 (USA's parts of Alaska and Canada's Northwest Territory). In each climate zone is defined Heating Degree Days (HDD).

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Degree days are defined as time above or below a "base" temperature. It is most common to use 18°C (65 °F) as the base temperature for heating. Degree days is essentially a simplified representation of outside air temperature. The heating degree is determined by the following example:

If the temperature where you reside stays at 10°C (50°F) for a period of 24 hours below the "base of 18 °C (65 °F)", that equates to 8 HDD18C (15 HDD65F). To convert HDD from Celsius to Fahrenheit: °F HDD = 9/5 x °C HDD

Note: Because the degree days measurement is relative to a "base" temperature, it is incorrect to add or subtract 32 when converting from Celsius to Fahrenheit (or vice versa).

Example 5: How to Use of the HDD Map and Climate Zone Table to Choose a Condensation Index (CI) for a Product

A developer plans to build a track of homes in several cities between Montpelier and Burlington in the state of Vermont. The developer wants fenestration products specified with minimal condensation potential based on the climate zones of all cities they plan to build. The developer looked up the heating degree days for Montpelier (8200 HDD65F = 4560 HDD18C) and Burlington (7400 HDD65F = 4110 HDD18C) and finds that those cities are in Climate Zone 6 of Table 7-2. Climate Zone 6 per the Figure 7-1 is approximately a Winter Design Temperature (WDT) of -18° C to -23° C (0°F to -10 °F. Finally, the developer wants to use the Condensation Index (CI) Table to help specify a rating range based on an average indoor home relative humidity of 50%.

Therefore, at 50% R.H, and a WDT between -18°C and -23°C, the CI range per the Condensation Index (CI) Table is 73-76.

		Winter Design Temperature, Td (Celsius)								
	***Dew Point Temp, Ts, °C**	0	-5	-10	-15	-20	-25	-30	-35	-40
RH%		**Condensation Index, CI**								
50	10	48	58	65	69	73	76	78	80	82

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8. ADDITIONAL INFORMATION AND READING MATERIAL

A. Residential Windows: A guide to new technologies and energy performance. Second Edition. John Carmody, Steven Selkowitz, Dariush Arasteh, and Lisa Heschong. W.W. Norton and Company. New York. 2000.

B. CSA A440.2-14/A440.3-14 - Fenestration energy performance / User guide to CSA A440.2-14, Fenestration energy performance

C. Window Systems for High Performance Buildings. John Carmody, Stephen Selkowitz, Eleanor S. Lee, Dariush Arasteh, and Todd Willmert. W.W. Norton and Company. New York. 2004.

D. 2018 International Energy Conservation Code®, International Code Council. 2017.

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